United States
Department of
Agriculture

Office of
Transportation

Marketing
Research
Report
Number 1109

Transportation and Handling Factors in Relation to Quality in Exporting Soybeans

Acknowledgments

The authors wish to thank the following research associates of the Science and Education Administration, Agricultural Research: Arif Abdul-Baki, Seed Research Laboratory, for his efforts as a project coordinator; James Koch, Biometrical Staff of the Northeastern Region, for his advice on statistical analysis in experimental planning and interpretation of the data; and Roy E. McDonald, Lawrence Risse, and Anton Bongers, European Marketing Research Center, for sampling the five shipments that arrived in Europe. In addition, personnel of the Federal Grain Inspection Service helped in collecting origin samples and provided other invaluable assistance to researchers. Personnel of the Foreign Agricultural Service also assisted in this project, not only in returning samples from overseas destinations, but in other expressions of active support.

Contents

June 1980

Transportation and Handling Factors in Relation to Quality in Exporting Soybeans

By C. J. Nicholas and M. E. Whitten[1]

Summary

In the 17 test shipments between sampling at loading and at unloading, both foreign material (FM)[2] and splits[3] increased during movement from the U.S. port to the overseas destination port, the former from an average of 1.6 to 1.8 percent, and splits from 12.2 to 14.2 percent.

Soybeans are handled 15 to 20 times while moving from the farm to the overseas receiver. Breakage or damage[4] increases as handling is repeated. The number of handlings not only increases the breakage, but also the cost. Industry sources estimate that marketing costs increase as much as 2 cents per bushel after each handling.

A significant analysis in soybean breakage is the development of the data on fine material, or fines.[5] Of the eight test shipments analyzed for fines, in one-third of the samples, fines made up one-half or more of the FM content, and in all the shipments fines constituted more than one-third of the FM present.

Shortages of grain hopper cars and barges presented a serious transport problem to the soybean shipper. Also, the cost of moving soybeans from the U.S. interior terminal elevator to the port of embarkation was high.

Insect infestation continued to present a problem, especially to soybean receivers in the Far East. Seven of the 11 shipments received in Japan were infested with insects and required fumigation.[6]

Analysis of "invoice" and "loaded" weights in 12 of the test shipments showed weight shortages in six of them, varying from 0.4 to 0.8 percent and averaging 0.5 percent.

Neutral oil content and free-fatty acids were determined on two shipments. One shipment showed a neutral oil loss of 3.3 percent at origin and 4.2 percent at destination and a 0.6 percent free-fatty acid content at both origin and destination, indicating a decrease in quality of the oil. In another shipment, neutral oil loss increased from 4.2 to 4.9 percent, while free-fatty acid content increased from 0.6 to 0.7 percent during transport.

Analysis of destination samples of four Brazilian soybean shipments showed the oil content 1 percent higher than in U.S. shipments, the protein content about the same, and free-fatty acids higher in the Brazilian beans, although the neutral oil losses were about the same as in the U.S. beans.

---

[1]Agricultural economist, Transportation and Packaging Research Branch, Office of Transportation; and research chemist (retired), Seed Research Laboratory, Science and Education Administration-Agricultural Research, respectively, Beltsville, Md. 20705.

[2]Includes soybeans and pieces of soybeans which will pass readily through an 8/64 round-hole sieve and all matter other than soybeans remaining on such sieve after sieving.

[3]Defined as soybeans with more than one-fourth broken off (U.S. Dept. Agr., Agr. Mktg. Serv. Grain Insp. Manual, p. 189, Instr. 918 (GR-6) (Aug. 1971).

[4]A term used synonymously with "breakage." Damaged kernels are soybeans or pieces which are heat-damaged, sprouted, frosted, badly ground-damaged, badly weather-damaged, moldy, diseased, stink-bug-stung, or otherwise materially damaged. (Official U.S. Standards for Grain, Federal Grain Inspection Service (FGIS), USDA, Wash., D.C., January 1978, p. 8.2)

[5]Pieces of broken soybeans which pass through an 8/64 round-hole commercial soybean cleaning sieve after the removal of other material.

[6]Tolerances for insects in Japanese customs regulations are much more restrictive than those provided in the Official U.S. Standards for Grain.

Introduction

Soybeans are the most important agricultural export cash crop in the United States. Their use is widespread in animal feeds, human foods, and industrial applications. As the world population continues to grow and animal protein becomes increasingly scarce, soybeans will likely play a vital role in supplying a larger share of the protein needs of the world. This trend is readily apparent when it is considered that world production of soybeans more than doubled over the past decade.

U.S. soybeans contribute more protein and oil to our food economy than any other single source. In 1971, for example, milk protein contributed nearly 4.7 billion pounds of the food protein consumed in the United States, whereas the soybean crop provided 27 billion pounds of protein. The remainder came from meat, fish, etc. Furthermore, developing protein foods from soybeans and other oil seeds is one practical approach to the solution of the world's food shortages.

Losses in quality of soybeans are largely the result of modern harvesting, transport, storage, and handling methods. It is estimated that soybeans are augured, dumped, and otherwise handled from 15 to 20 times between the farm and delivery to the final foreign customer. This often results in quality deterioration and breakage that seriously concerns both the overseas and the domestic buyers.

Grain standards for soybeans do not adequately reflect the end use characteristics of the soybeans. Since approximately 70 percent of the soybeans marketed by farmers in the United States are No. 1 grade (1 percent maximum FM) when harvested, and most export orders are No. 2 grade (2 percent maximum FM)[7], there is an economic incentive for exporters to take advantage of this difference.

Finally, an important source of complaints by foreign receivers is the high concentration or pockets of FM in loads caused by stratification of FM during loading of ships. The U.S. export certificate for grains represents the average quality for the total load on the ship, and not the quality of any particular portion or sublot.[8] Very often, due to this stratification in the hold, there are wide variations in the percentage of FM within it, which result in varying amounts of FM in different parts of the hold. Parcels unloaded first often contain the least FM.

Twenty-five formal overseas soybean complaints on excessive FM, short weights, grading, etc., were received by USDA's Foreign Agricultural Service (FAS) in 1976. Of the 16 formal soybean quality complaints received by FAS in calendar year 1977, most pertained to excess FM. Although additional complaints were made informally, some overseas buyers, in conversations with researchers, expressed hesitancy to register complaints for fear of jeopardizing their supply sources in the United States.

The research reported here is part of a broader project to find ways of reducing transport, handling, and storage costs and quality losses for shipments of U.S. soybeans to both foreign and domestic markets. Its objectives are to identify and measure the types and extent of physical damage and quality losses, and to assess the feasibility in introducing alternative methods. These objectives are being implemented by documenting quality differences between origin and destination, studying ways for reducing physical and quality losses during handling and transport, and developing alternative handling and transport methods in order to minimize these losses.

---

[7] Official U.S. Standards for Grain, Federal Grain Inspection Service (FGIS), USDA, Wash., D.C., July 1977, p. 8.4.

[8] Grain and soybeans of other than U.S. origin are exported under a "fair average quality" (FAQ) contract, where quality is guaranteed to be equal to the average of all such grain shipped during a given period. In contrast to the U.S. certificate final system, the FAQ contract calls for quality to be determined at the port of import, rather than the port of export.

Method of Study

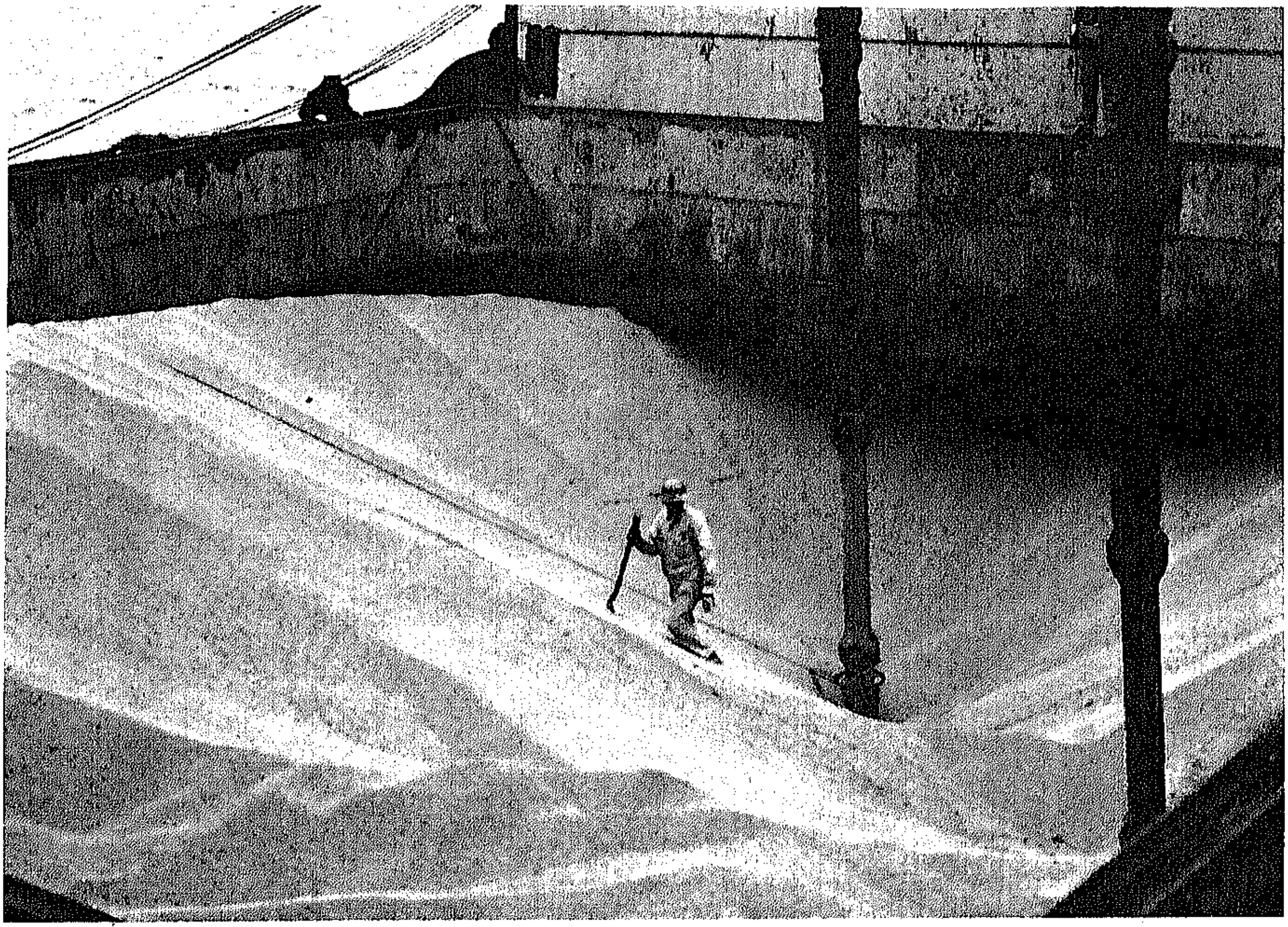


Figure 1.—Pneumatic unloading system, or "suckers," unloading soybean test shipment in Japan.

This is the third progress report[9, 10] presenting results of a series of test shipments initiated in this study. Planning a test program for soybeans for any duration of time is difficult because of constant changes in demand, prices, economics, weather, shipping, storage, and destination sampling conditions.

Test Shipments

The test program in this study was developed by researchers sampling selected shipments during loading at the U.S. port of embarkation and again during unloading at the overseas destination port. Economic and physical performance data were collected. Different elevators, ports of embarkation, modes of transport, and ports of destination were sought for the study. Most U.S. soybean shipments originated at large grain export elevators on the Gulf and East Coasts. In two of the test shipments researchers were able to arrange with the shippers to maintain the identity of the soybeans by drawing the original samples at the interior terminal elevator, continuing to take samples at each transfer point, and sampling when the soybeans were unloaded at the overseas port.

---

[9]Nicholas, C. J. Analysis of selected shipments of U.S. and other soybeans received in Japan, 1972-76. USDA, ARS-NE-92. 1978.
[10]Nicholas, C. J. and M. E. Whitten. Analysis of soybean shipments at U.S. origin and overseas destination. USDA, MRR 1090. 1978.

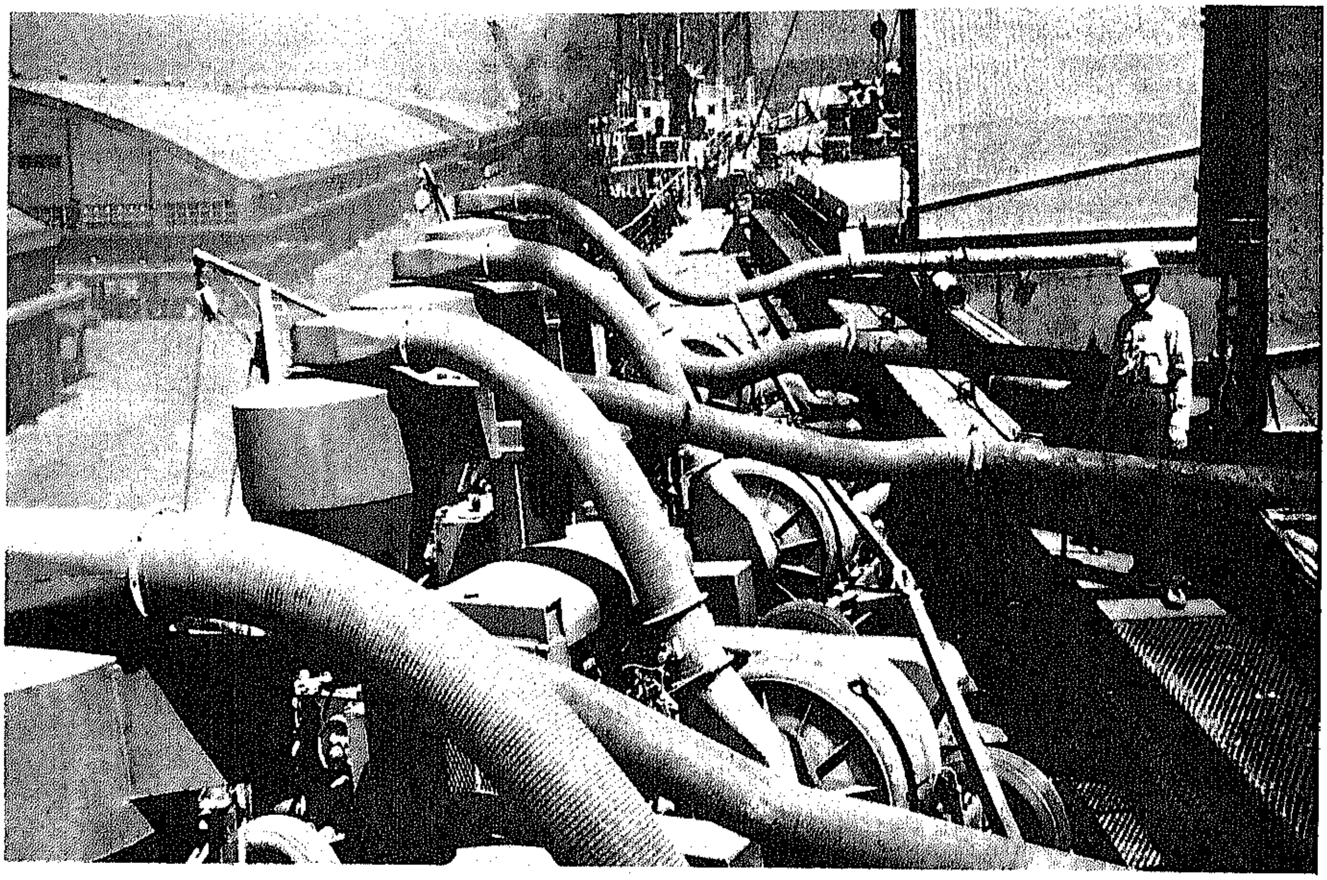


Figure 2.—VAC-U-VATORS used to unload soybean test shipment in Taiwan.

Movements through the export elevators were constant and the quantities so large that soybeans were seldom stored and those currently arriving at the export elevator were used to fill immediate shipping requirements. Therefore, most test shipments in this study were commercial grain movements in the export channels, and were sampled at the port elevator and the overseas destination.

In the United States researchers used methods approved by the USDA's Federal Grain Inspection Service (FGIS) to sample export shipments. Soybeans moving through the elevators were sampled mechanically. Shipments moving by railcar, barge, or truck were sampled manually by grain probe. Mechanical sampling and inspection of soybean export shipments are not only generally accepted, but also required by the U.S. Grain Standards Act of 1976.

All the test shipments were graded by FGIS as No. 2 yellow soybeans, except two (shipments 31E227 and 33E727), which were graded as No. 3 yellow soybeans based on FM and splits.

Sampling

Sampling soybean test shipments overseas was a problem because mechanical samplers are not used extensively in Europe and the Far East.

In Japan, sampling was performed by a contractor who followed specific guidelines issued by researchers on the advice of the FGIS. (See Appendix, Example 1.) Japanese test shipments were restricted to those elevators where sampling by an Ellis cup[11] or a pelican sampler[12] was possible. Probes were used to sample soybeans loaded in barges only.

[11]A hand-dip sampling device which is dipped into grain moving on a conveyor in three places across the belt in such a way that the cup fills with grain as it is lifted.

[12]A leather pouch which is swung through a stream of grain to obtain a representative sample.

Sampling in Europe was performed primarily by personnel of the USDA European Marketing Research Center located at Rotterdam, the Netherlands. Five test shipments unloaded in Europe were sampled by grain probe and Ellis cup on the basis of grid patterns developed by Agricultural Marketing Service statisticians.

Studies of the modes of transport used from the interior of the United States to the port involved service, cost, and availability, compared with various alternative modes. Transport modes were studied also in relation to splits and damage.

Ocean transportation was studied specifically to determine the effect that movement by bulk carriers and general cargo ships (tween-deckers) had on the amounts of damage or splits contained in the soybeans. Ocean transport costs were considered and related to soybean prices.

Elevator operations, handling methods, and rates of loading and unloading were studied and analyzed. Comparisons were made with the rates of soybean breakage associated with each type of operation.

There were 17 test shipments sampled at U.S. origins and overseas destinations. Four of these left the United States from East Coast ports, while the others left from Gulf ports. Ten shipments were unloaded in Japan, six in Europe, and one in Canada.

Four shipments were sampled at terminal elevators, the movement consisting of three grain train shipments of 100 railcars each that went to an East Coast port. Three of the other shipments were represented by 25 barges each, loaded in interior points in Iowa and Illinois and moved down the Mississippi River to the Gulf. Each of these shipments also were made up of two grain trains.

Four Brazilian shipments were sampled only at destination at the time of unloading in Japan, and these samples were chemically analyzed and compared to U.S. soybeans.

Most of the grain elevators in the United States from which the test shipments originated had the same types of handling and conveying systems. Most of the soybeans shipped to export elevators in the Gulf area moved by barge. Barges were unloaded at the export elevators by "marine legs," or bucket elevators, and the soybeans were conveyed to a bin, a scale for weighing, a garner or hopper, a mechanical sampler, a conveying belt, a shipping bin, and, finally, to the ship for export.

The grain elevators in Japan generally had chain drag systems to move the soybeans into the elevator. In Europe, chain drags or conveyor belts were used. Unloading was primarily by pneumatic systems, or "suckers," (fig. 1), although one overseas elevator used VAC-U-VATORS (fig. 2) and "clam shell" buckets. Only one overseas elevator where a test shipment was unloaded was equipped with a "marine leg" or bucket elevator.

Chemical Analysis

Analyses for moisture, oil, protein, and free-fatty acids were made by official methods of the American Oil Chemists' Society on the first 20 shipments described in an earlier report.[13] After an inhouse study proved that the near-infrared reflection method for determining oil, moisture, and protein content was satisfactory, this method was used for oil and protein determinations on subsequent shipments.

The oil in soybeans is composed of neutral oil (triglycerides), free-fatty acids, gums (phosphatides), and some minor constituents. When the crude soybean oil is refined, it is first degummed by the addition of water to the oil. The water hydrolyzes the gums into solids so they may be centrifuged. The free-fatty acids are then removed by refining with an alkali.

The free-fatty acids (chiefly oleic acid, linoleic acid, and linolenic acid) are a good indication of the value of soybean oil. However, the gums or phosphatides vary so much that the neutral oil loss (free-fatty acids and phosphatides) is a much more realistic test. It is this test that buyers and oil mill operators use in buying and selling soybean oil. When soybeans are stored, the free-fatty acids in the oil slowly rise as oxygen causes the neutral oil to split into free-fatty acids and water. When the bean is whole, its viability retards deterioration. When the hull is removed or the bean splits, the breakdown of oil into fatty acids increases. When the bean is broken further into pieces and bits, the breakdown is further accelerated.

It can be readily seen that care in handling soybeans can have a decided effect on the quality of oil available, and therefore on the value of the beans.

---

[13] See footnote 10 on p. 7.

Data Analysis

The free-fatty acid measurement, which was made on all test shipments, has been used as an indicator of the quality of soybeans; however, this method was not sensitive enough to determine small changes in quality during transport. On the other hand, the neutral oil loss determination was sensitive enough to measure the changes. A laboratory method was therefore devised to simulate the commercial method used for determining neutral oils in processing of soybeans. On two shipments, oil obtained by this procedure was analyzed for neutral oil loss, and the results were those used in the commercial purchase and sale of soybean oil.

The laboratory processing method used consisted of dehulling soybeans in an attrition mill[14], subjecting them to heat and vacuum to further lower the moisture content, followed by the addition of steam to "cook" the beans and further treatment by heat to drive out excess moisture. While hot, the beans were flaked to about 0.007- to 0.010-inch thicknesses and extracted with hot hexane for 1 hour. The solvent was removed, and the resulting oil was analyzed for neutral oil content.

Neutral Oil Loss

Neutral oil loss is a chemical determination or laboratory measure which removes all material from the oil except the triglycerides. This loss includes free-fatty acid, phosphatides, and other material. Since this analysis (together with the color of refined oil) is used to determine the quality of soybean oil in purchase and sale, it is an important indicator of oil quality, and therefore of bean quality. Future study of the quality of soybeans during shipment should, therefore, include this important factor. Preliminary tests were run on a number of test samples produced commercially on crude soybean oil extracted from soybeans in the laboratory. The laboratory method used was found to accurately indicate the value of the oil that could be obtained from soybeans commercially.

[14]A disc-type attrition mill used to crack the soybeans prior to cooking.

The 17 test shipments in table 1 represent a total of 462,000 tons sampled at both origin and destination. About 300,000 tons were sampled at destination by Ellis cup, 155,000 tons by grain probe, and 7,000 tons by pelican sampler. Of the 155,000 tons sampled by probe, 80,000 tons were sampled in Europe following probe patterns developed by statisticians.

Sampling

Sampling at destination was performed according to sampling procedures developed by FGIS. On two shipments to Europe, grid sampling patterns were developed by Semper.[15] (See Appendix, Examples 2 and 3.) The sampling patterns were carried out by grain probes on a sector level and on a depth basis in the hold, and by Ellis cup on the incoming conveyor belts. Analysis of the probe samples for shipments 13E613 and 31E227 disclosed that significant differences existed between sections within a level, which was an indication that the soybeans were not uniformly loaded within the hold. The differences in results found in FM between mechanical samples drawn at origin and Ellis cup samples drawn at destination were not significant. However, the probe-sampled FM data obtained at destination averaged higher than FM content in samples drawn by the Ellis cup or the diverter.

Further analysis of shipment 13E613 indicated an increase in the amount of FM. The only other difference between the data for test weight, heat damage, damaged kernels, and splits that can be attributed to something other than sampling variability was the difference for splits. The difference or sampling error was significant at the 0.01 level. In other other words, 99 percent of the samples drawn reveal a meaningful difference between the data on splits at origin and at destination.

In shipment 13E613 and 31E227, the major portion of the variability in the samples was attributed to the level in the depth of the load. The conclusion drawn on the basis of both shipments indicated that more precise measurements of shiplot quality can be obtained by increasing the number of sectors sampled at each level in the ship's hold.

Many earlier studies have been related to the marketing problems in static-load-based storage situations which can be applied more easily to handling and transport problems. In contrast, this study includes the handling and transport of soybeans moving in the marketing system. This research is subject to more random and

[15]Randall C. Semper, Statistical Services Group, TSD, Agricultural Marketing Service

Table 1.—Selected U.S. soybean observation test shipment schedule, 1976-78

Shipment No.	Soybean tonnage[1]	Crop	Destination	Ship's hold: Depth	Ship's hold: Length	Time from loading to final discharge	Rate of loading	Rate of unloading	Destination sampling: Method[2]	Destination sampling: Rate
	Long tons	*Year*	*Country*	*Feet*	*Feet*	*Days*	*Bu/hr*	*Bu/hr*	*Type*	*Bu/hr*
11A414	31,630	1975	Japan	55	48	45	15,050	15,500	Mechanical	11,000
									Probe	2,200
								8,400	Ellis	8,150
12A522	38,525	do	do	55	63	46	9,300	7,000	do	7,700
13E613	31,100	do	England	61	54	45	20,000	24,000	Probe	21,400
									Ellis	8,320
15A620	31,825	do	Japan	55	59	36	23,800	10,600	do	11,600
16A627	26,475	do	do	47	48	35	41,300	22,950	Probe	1,450
								14,340	Mechanical	11,900
18A825	20,635	do	do	50	91	32	34,400	15,330	Ellis	18,830
19A315	23,150	do	Taiwan	45	71	38	40,000	22,940	Probe	13,100
20A413	25,880	do	do	46	86	35	36,500	15,200	do	16,080
29E277	29,440	1976	Japan	54	97	46	45,930	10,570	Ellis	13,210
									Probe	2,790
								15,240	Mechanical	11,010
30A218	23,690	do	do	46	93	41	5,000	12,960	Ellis	20,850
									Probe	2,000
31E227	14,250	do	Denmark	46	52	21	35,510	6,100	do	9,000
32E507	15,630	do	England	64	45	24	8,940	20,520	Ellis	15,630
									Probe	15,630
33E727	7,700	do	Italy	62	43	26	10,000	6,390	do	7,700
34A416	30,140	1975	Japan	54	56	42	15,380	8,490	Ellis	10,300
								17,110	Pelican	2,820
36S120[3]	15,880	1977	Canada	58	95	13	20,980	41,710	Ellis	15,880
40A119	51,180	do	Japan	60	55	54	12,590	16,920	do	18,910
								24,510	do	8,060
									Pelican	3,770
42A318	45,775	do	do	56	48	44	57,720	17,890	Mechanical	8,110
								7,000	Ellis	5,380

[1]Weight of soybeans loaded aboard ship.
[2]Sampling methods used were the mechanical, manual probe or grain trier, Ellis cup, and pelican sampler.
[3]Test shipment moved from U.S. port on Great Lakes to a port in Canada.

Table 2.—Analysis of foreign material (FM) in selected soybean test shipments at origin and destination by sampling method, range of confidence, and range of samples, 1976-78

Shipment No.	Origin				Destination					
	Samples	Mean FM	Range of confidence[1]	Actual range of samples	Samples	Sampling method	Mean FM	Range of confidence[1]	Actual range of samples	Subsamples with over 2 percent FM
	Number	*Percent*	*Percent*	*Percent*	*Number*	*Type*	*Percent*	*Percent*	*Percent*	*Percent*
11A414	22	1.6	1.524-1.748	1.0-2.0	9	Ellis cup	1.7	1.183-2.304	0.8-2.9	33
12A522	36	1.6	1.544-1.716	1.1-2.4	8	do	1.7	1.215-2.185	1.0-2.5	38
13E613	29	1.7	1.658-1.838	1.4-2.3	27	do	2.0	1.527-2.510	.9-7.1	37
					92	Probe	2.8	2.490-3.139	.5-8.9	37
15A620	25	1.5	1.389-1.699	.8-2.3	12	Ellis cup	1.5	.899-2.167	.7-4.3	17
16A627	17	1.5	1.375-1.565	1.2-1.8	5	Probe	1.6	.561-2.559	.8-2.9	20
18A825	16	1.6	1.438-1.762	.8-2.0	16	Ellis cup	1.7	1.219-2.093	.7-4.2	31
19A315	22	1.7	1.588-1.812	1.2-2.2	15	Probe	2.5	1.777-3.222	.9-5.3	53
20A413	24	1.7	1.599-1.817	1.1-2.1	18	do	1.8	1.412-2.131	.8-3.8	39
29E277	21	1.1	.985-1.311	.3-1.7	20	Ellis cup	1.4	1.075-1.795	.7-4.2	10
30A218	74	1.5	1.417-1.573	.9-2.4	29	do	1.5	1.271-1.799	.6-4.3	10
31E277	14	2.8	2.595-2.976	2.3-3.3	102	Probe	3.2	2.790-3.620	.2-9.9	68
32E507	52	1.7	1.515-1.785	.9-3.0	53	Ellis cup	1.9	1.703-2.035	.8-5.9	36
					31	Probe	2.3	1.855-2.779	.8-6.3	52
33E727	25	1.4	1.295-1.593	.9-2.1	66	do	1.6	1.407-1.705	.7-2.9	26
34A416	19	1.6	1.484-1.674	1.2-2.0	11	Ellis cup	1.6	1.268-1.696	1.1-2.0	0
36S120	49	.8	.706-0.956	.2-1.9	54	do	1.1	.885-1.229	.4-3.8	7
40A119	39	1.8	1.763-1.883	1.4-2.1	47	do	1.8	1.365-1.869	.5-3.8	28
					21	do				
42A318	28	1.7	1.543-1.765	1.0-2.4	14	do	1.7	1.233-2.153	.9-3.8	21
Weighted average		1.6					1.8			
Overall range				0.2-3.3					0.2-9.9	

[1]95-percent confidence level.

nonrandom sampling variations[16] as well as many other variables inherent in the U.S. grain marketing system.

Use of the various sampling methods shown in table 2 also caused some differences in FM because of changes in location in the load from which the samples were drawn. By the development of an arithmetic mean of the FM destination samples obtained from means with their confidence interval and the range of confidence, as shown in table 2, a definite pattern of increase in FM between origin and destination is apparent.

Foreign Material

Table 2 records the amount of FM found in test shipments from samples drawn during loading and unloading. From the wide range of FM data at origin, it became apparent that there was no uniformity or homogeneity in most of the soybean cargoes during loading aboard ship, and there were often heavy concentrations, or "pockets," of FM in the load during unloading.

The analysis of FM shown in table 2 shows a general increase between origin and destination with a weighted average of 1.6 percent at origin and 1.8 percent at destination. With origin samples varying from 0.2 to 3.3 percent and destination samples from 0.2 to 9.9 percent, the range of confidence at the 95-percent level tested the validity of these ranges. The increased FM in the range of the samples in many shipments between origin and destination indicated cumulative breakage. In 12 of the 17 destination shipments, more than 25 percent of the subsamples contained over 2 percent FM in excess of the grade limit. Multiple deliveries with spout-line separations and uneven loadings sometimes caused destination samples to lack consistency.

Splits

Table 3 records data on splits as determined from origin and destination samples. The weighted averages for splits were 12.2 percent at origin and 14.2 percent at destination.

Analysis of splits in the test shipments shows a weighted average at origin of 12.6 percent, with an actual range of 4.0 to 23.4 percent, and a weighted average at destination of 14.2 percent, with a range of 3.6 to 39.8 percent. Discounting sampling variability, the use of different sampling methods, and multiple deliveries, increases in both the weighted average and the range of samples at destination indicate that splits increased with repeated handlings as the shipments moved from origin to destination.

Handling

The soybeans studied were handled about 15 to 20 times from the time they were harvested until they reached the consumer. The various handling operations included equipment such as screw conveyors, vertical bucket elevators, drop spouts, and grain throwers. Mechanical handling, high-speed loading and unloading, and gravity drops into storage bins and ships contributed to the breakage. In addition to the breakage caused by additional handling, industry sources stated that each handling increased soybean costs by about 2 cents a bushel.

Handling included loading and unloading soybeans into and out of the elevators as well as movement by belt conveyors within the elevators. On the basis of a number of observation tests made, there was no appreciable difference in the rate of breakage of the soybeans due to the speed of the belts or the loading and unloading rates. Breakage was more directly caused by impact and varied with the impact surface.

The grade factors of FM and splits were studied in relation to handling at the export and import elevators. Table 4 compares the rate of loading and unloading at U.S. and overseas ports with the percentage of splits and FM found in the soybean samples. FM and splits recorded in the test shipments followed the same general trend (figs. 3 and 4), with little or no relationship between the rate of loading (up to 45,000 bu/hr) and breakage.

Figure 4 charts the rate of unloading overseas with the FM and splits applicable to each shipment. There appears to be only a limited relationship between the splits and FM recorded at destination and the unloading rates at the overseas elevators.

Fines

An analysis of the data on FM, splits, and fines is shown in table 5. Of the eight shipments analyzed, one-third of the samples had fine material which made up one-half or more of the FM content. All of the shipments had fine material constituting more than one-third of the FM content. The weighted average of the FM is 1.95 percent, and for fine material 0.96 percent, indicating the prevalence of fine material.

[16]The three types of nonrandom variations can be minimized through proper blending, sampling, and measurement. Random variation is inevitable where an element of chance is introduced, as when a sample, as opposed to the whole unit, is used for grade determination.

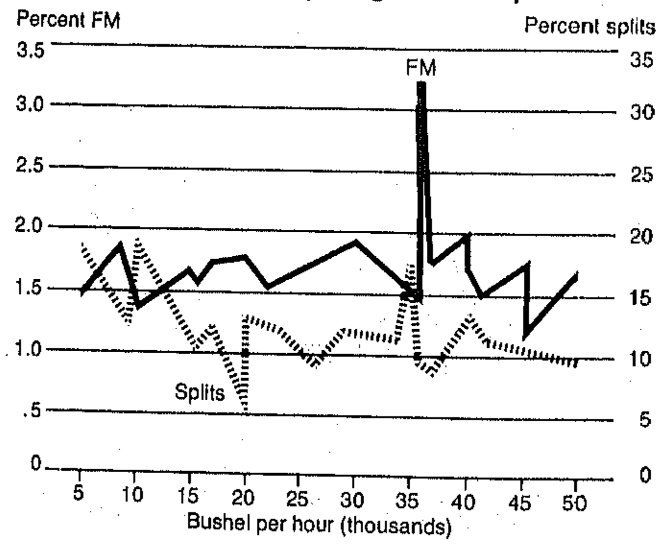
Table 3.—Analysis of splits in selected soybean test shipments at origin and destination per sampling method, range of confidence, a

Shipment No.	Origin: Samples	Origin: Mean splits	Origin: Range of confidence[1]	Origin: Actual range of samples	Origin: Moisture content	Destination: Samples	Destination: Sampling method	Destination: Mean splits	Destination: Range of confidence[1]	Destination: Actual range of samples
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Type*	*Percent*	*Percent*	*Percent*
11A414	22	10.1	8.868-11.403	7.2-16.8	12.2	9	Ellis cup	11.6	9.196-13.914	8.3-17.4
12A522	36	12.5	11.875-13.075	9.3-18.8	11.8	8	do	13.2	12.067-14.283	11.3-15.5
13E613	29	12.0	11.390-12.554	9.1-16.0	11.7	28	do	15.6	14.924-16.268	11.8-20.6
						100	Probe	16.4	15.677-17.196	9.5-39.8
15A620	25	12.5	11.323-13.636	9.0-21.5	11.7	12	Ellis cup	14.4	13.235-15.580	10.9-17.1
16A627	17	11.7	10.299-13.087	8.2-18.7	11.4	5	Probe	11.8	8.107-14.932	6.9-13.8
18A825	16	10.9	9.882-11.842	8.3-14.0	11.4	16	Ellis cup	12.8	12.101-13.405	10.8-14.9
19A315	22	13.1	12.068-14.117	10.0-20.0	12.8	15	Probe	14.0	12.860-15.113	9.7-16.9
20A413	24	9.2	8.172-10.169	5.7-13.6	12.2	18	do	10.4	9.380-11.508	6.0-15.3
29E277	21	10.2	9.729-10.717	8.5-12.2	11.6	20	Ellis cup	12.4	11.198-13.692	8.1-19.6
30A218	74	17.1	16.647-17.647	12.9-22.0	11.9	29	Ellis cup	20.8	19.469-22.151	14.8-30.0
31E277	14	16.7	15.965-17.477	14.9-18.5	11.1	101	Probe	19.0	18.401-19.517	10.4-27.4
32E507	52	13.4	12.737-14.073	8.1-18.6	11.5	53	Ellis cup	15.7	15.280-16.168	12.5-20.5
						31	Probe	16.3	15.088-17.576	10.4-24.3
33E727	25	18.8	17.979-19.548	15.3-23.4	11.7	66	do	22.1	21.509-22.692	15.6-27.2
34A416	19	10.6	9.750-11.460	8.4-14.4	12.2	11	Ellis cup	12.4	11.324-13.493	9.8-15.4
36S120	48	5.8	5.479- 6.197	4.0- 9.6	13.9	52	do	6.8	6.512- 7.076	3.6- 8.9
40A119	39	11.8	11.349-12.224	8.8-13.7	13.4	47	do	13.2	12.511-13.977	8.4-18.4
						21	do	12.4	11.885-12.952	9.9-14.6
42A318	28	12.8	11.880-13.662	9.1-18.1	12.7	14	do	14.9	14.398-15.358	13.7-16.7
Weighted average		12.2						14.2		
Overall range				4.0-23.4						3.6-39.8

[1]95-percent confidence level.

Figure 3

Rate of Elevator Loading (bu/hr) in United States of Test Shipments Comparing FM and Splits



range of samples, 1976-78

Moisture content	Samples higher than the destination mean	Increases between origin and destination
Percent	*Number*	*Percent*
11.7	4	44
11.7	3	38
11.2	12	43
11.0	45	45
11.3	6	50
11.2	4	80
11.5		
12.2	9	60
12.5	10	56
11.5	11	55
12.0	14	48
11.0	45	45
	26	49
11.8	13	42
11.8	35	53
11.9	5	46
14.0	28	17
13.3	25	53
12.7	9	43
12.8	6	43

Figure 4

Rate of Elevator Unloading (bu/hr) Overseas of Test Shipments Comparing FM and Splits

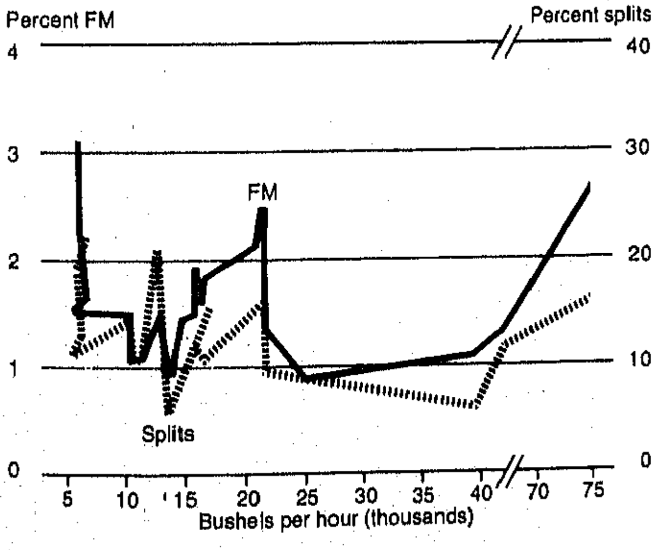


Figure 5 shows that the quantity of "other material"[17], a constituent of FM, was lower than that of fine material in most samples, amounting to less than half the quantity of fines.

Prices

Table 6 shows sale prices of soybeans, ocean freight charges required to move them to their overseas destination, and the grades and quality factors for selected test shipments.[18] Soybean prices during this 2-year period varied considerably, moving from a low of $176.75 per metric ton in the spring of 1976, to a high of $375.50 per metric ton in the spring of 1977. The ocean freight rates shown were charged for chartering tramp steamers,[19] and they generally followed a supply-demand pattern.

The widely fluctuating soybean prices during 1976-78, as listed in table 6, were due to increased world demand for soybeans, especially the derived demand for their use in the production of soybean oil and meal. There was no relationship between soybean prices, freight charges, or the respective grade and quality factors, nor was there a direct correlation between the oil content and prices. However, there was a general trend applicable to both the oil content and prices. Although the marginal value of a bushel of soybeans is determined by its oil and protein content, the present practice of evaluating soybeans based on visual inspection and measured moisture content sometimes does not express the intrinsic value of the product (fig. 6).

[17]Any material that will pass through an 8/64 round-hole sieve except broken soybean pieces. Consists of weed seeds, pieces of soybean pods and stems, broken pieces of other grains, sand, and/or earth fragments.

[18]One of the major grain marketing firms provided the researchers a confidential list of 28 cost items for exporting soybeans; these costs varied so much from shipment to shipment that it was not possible to obtain a very useful estimate of average cost for exporting soybeans. The more important of these costs were for stevedoring, demurrage, ocean freight, shrinkage, and lighterage; the largest single cost item was for ocean freight.

[19]Contractual agreement between the carrier and shipper negotiated by brokers representing the respective parties and referred to as a charter party. This agreement is usually a voyage charter and provides for the use of the vessel for one or more voyages between designated points. The owner assumes full responsibility for operation of the ship and custody of the cargo.

Table 4.—Comparison of selected shipments at origin and destination of movement rate, transit time, and depth of ship's hold with splits and foreign material (FM), 1976-78

Shipment No.	Rate of loading	Rate of unloading	Depth of ship's hold	Mean splits Origin	Mean splits Destination	Mean FM Origin	Mean FM Destination	Time from loading to discharge
	Bu/hr	*Bu/hr*	*Feet*	*Percent*	*Percent*	*Percent*	*Percent*	*Days*
11A414	15,000	15,000	55	10.1	11.6	1.6	1.5	45
12A522	9,300	7,000	55	12.5	13.2	1.6	1.7	46
13E613	20,000	74,000	61	12.0	16.2	1.7	2.6	45
15A620	23,800	10,600	55	12.5	14.4	1.5	1.5	36
16A627	41,300	22,950	47	11.7	11.8	1.5	1.6	35
18A825	34,400	15,300	50	10.9	12.8	1.6	1.7	32
19A315	40,000	22,900	45	13.1	14.0	1.7	2.5	38
20A413	36,500	15,200	46	9.2	10.4	1.7	1.8	35
29E277	45,900	10,500	54	10.2	10.5	1.1	1.2	46
30A218	5,000	12,900	46	17.1	20.8	1.5	1.5	41
31E227	35,500	6,100	46	16.7	19.0	2.8	3.2	21
32E507	8,900	20,500	64	13.4	15.9	1.7	2.1	24
33E727	10,000	6,300	62	18.8	22.1	1.4	1.6	26
34A616	15,300	8,400	54	10.6	12.4	1.6	1.5	20
36S120	20,000	40,000	58	5.8	6.8	.8	1.1	13
40A119	40,000	14,000	50	11.8	13.0	1.8	1.5	47
42A318	45,000	20,000	55	12.8	12.7	1.7	1.4	40

Table 5.—Analysis of damages to soybeans for selected shipments during unloading by splits, foreign material (FM), and fines

Shipment No.	Unloading rate	Sampling method	Samples	Splits	FM	Fines[1]	Other material[2]	Fines portion of FM
	Bu/hr	*Type*	*Number*	*Percent*[3]	*Percent*[3]	*Percent*[3]	*Percent*[3]	*Percent*
28A180	10,000	Ellis cup	2	10.5	1.1	0.45		41
	16,310	Mechanical	3	6.7	.8	.43		54
29E277	10,570	Ellis cup	2	14.1	1.6	.70	0.40	44
	15,240	Mechanical	2	7.4	.7	.35	.20	50
30A218	12,960	Ellis cup	5	21.6	1.4	.52	.16	37
31E227	6,100	Probe	15	19.1	3.1	1.77	.69	57
32E507	20,000	Ellis cup	7	15.8	1.9	.49	.30	26
	20,520	Probe	6	17.0	3.0	1.58	.28	53
33E727	6,390	Probe	8	22.2	1.3	.68	.33	52
38B119	6,270	Ellis cup	3	9.1	1.2	.60	.23	50
	9,230	Mechanical	3	8.6	1.2	.67	.20	56
39B131	11,210	Ellis cup	1	9.4	2.2	1.20	.60	55
	7,020	Ellis cup	2	9.6	1.5	.65	.30	43
	16,090	Mechanical	2	6.0	1.0	.30	.25	30
Weighted average—total				15.78	1.95	0.96	0.39	49

[1]Pieces of broken soybeans which pass through an 8/64 round-hole commercial soybean cleaning sieve after the removal of other material.

[2]Any matter that is not broken soybean pieces and consists of weed seeds, broken pieces of other grains, sand, and/or earth fragments that will pass through an 8/64 round-hole sieve, and pieces of soybean pods and stems.

[3]Mean percent of total sample for each sampling method.

Figure 5

Fines, "Other Material," and FM as a Percent of Total Shipment

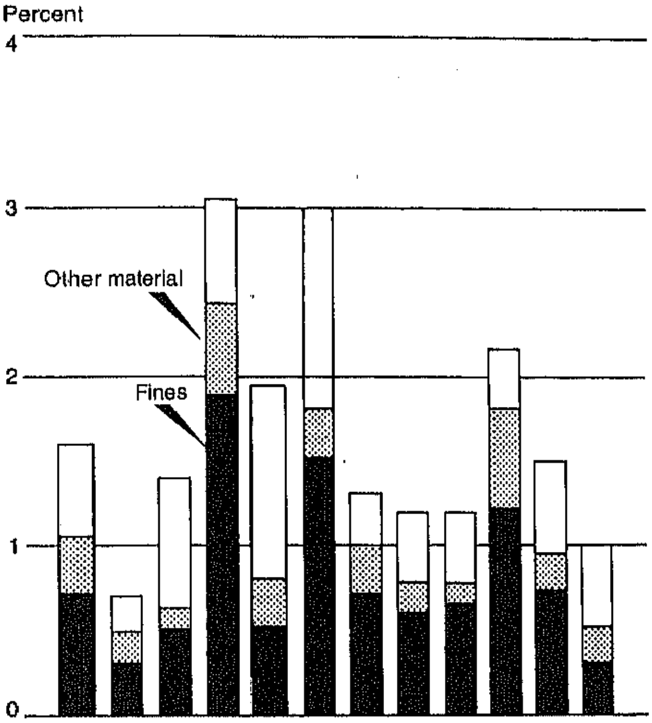
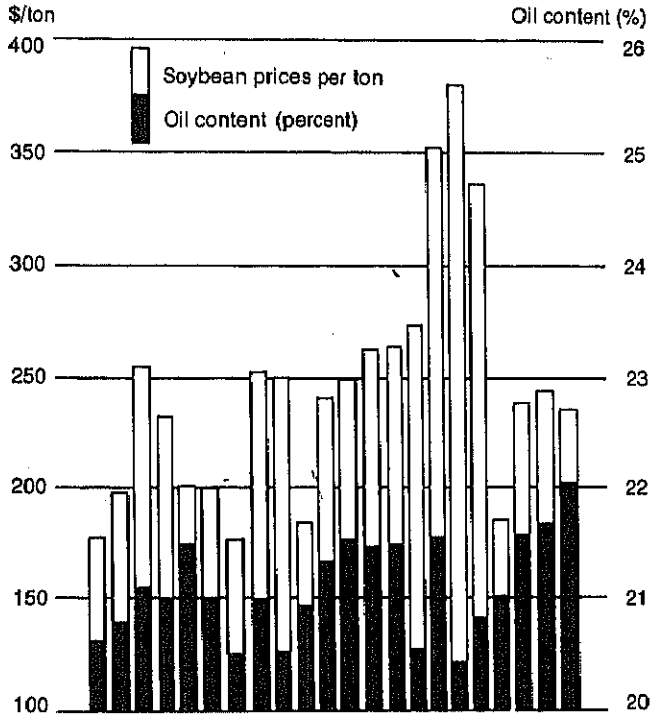


Figure 6

Prices and Oil Content of Soybean Test Shipments, 1976-77



Transportation

Handling and transport costs for moving soybeans during the 1976-78 period from the farm to the overseas receiver were significant. These costs for shipment No. 29E227, from a terminal elevator in the United States to Rotterdam, the Netherlands, are given below:

	Transport and handling cost, per bushel	
Price to farmer at country elevator..	$7.20	
Country elevator margin..........	.10	
Movement from Iowa (unit-train average)....................	.28	
Elevation at New Orleans.........	.04	
Value f.o.b. New Orleans........		$7.62
Ocean freight..................	.25	
Destination charges, including discharge, brokerage, and insurance....................	.05	
Value C.I.F. Rotterdam..........		$7.92

Table 6.—Prices, freight costs, and destination grade and quality factors for selected soybean test shipments from the United States to Europe and the Far East, 1976-78

Date	Shipment No.	Soybean prices	Ocean[1] freight	Foreign material	Splits	Oil content	Protein	Free-fatty acids
Year		*Dollars/MT*	*Dollars/MT*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1976	11A414	176.75	9.25[2]	1.8	9.8	20.8	40.6	0.6
	12A522	190.00	9.25	1.7	13.2	20.9	40.7	.6
	13E613	257.00	8.00[3]	2.6	16.3	21.3	40.3	.6
	14A619	230.51	9.50	.9	6.8	21.0	40.3	.5
	15A620	204.00	9.72	1.5	14.4	21.6	40.4	.7
	16A627	200.00	9.00	1.4	9.5	21.1	40.1	.5
	17A703	254.19	9.50	1.8	11.5	21.1	39.3	.5
	18A825	250.86	9.25	1.7	12.8	20.6	40.3	.7
	19A315	177.23	15.80	2.5	14.0	20.6	40.3	.8
	20A413	179.82	12.76	1.8	10.4	20.9	40.9	.6
	22A717	237.54	9.00	2.2	12.2	21.3	40.6	.9
	25E207	250.00	8.00	1.0	10.7	21.6	40.8	.5
1977	28A180	263.81	9.00	.9	8.2	21.3	39.9	.4
	29E277	266.40	8.00	1.2	10.5	21.5	39.7	.6
	30A218	274.47	9.63	1.5	20.3	20.6	40.2	.6
	31E227	337.00	12.50	3.2	19.0	21.6	40.6	0.6
	32E507	375.50	5.60	2.1	15.9	20.4	40.0	.6
	33E727	314.50	6.00	1.6	22.1	20.8	40.2	.7
	34A416	182.35	9.25	1.8	12.6	21.1	40.6	.5
1978	36S120	235.00	4.50	1.1	6.8	21.6	41.0	.6
	40A119	241.00	9.50	1.5	13.0	21.7	40.2	1.3
	42A318	234.00	8.30	1.4	12.7	22.1	39.4	1.0

[1]Sharply escalating fuel costs in 1979 boosted ocean freight costs dramatically.
[2]1979 ocean freight charges to Yokohama are about $35.00 M/T.
[3]1979 ocean freight charges to Rotterdam were about $16.00 M/T.

Several facts are evident, based on the above data:

1. Costs for moving soybeans in the United States from the country elevator to the export elevator are considerably greater than those for moving them from the export elevator to a foreign port.
2. It costs money each time soybeans are moved from one conveyance to another. This handling cost was probably a minimum of 2 cents, and averaged 5 cents per bushel.
3. Profit margins at the local elevator are higher than at U.S. or foreign ports, since volume is less than at an export elevator or a modern port such as Rotterdam, where the volume is great and the margin is small.

Severe shortages of transport equipment, rail hopper cars, and river barges during this period added indirectly to the cost of the soybeans. Rail hopper car shortages varied widely from 10,000 to 30,000 cars per day, a situation which added to the storage or warehousing costs, which were running about 5 cents per bushel. This shortage of transport equipment was acute immediately following the harvest season, when both storage and transport equipment were taxed to capacity.

Shortage of grain transport equipment, prevalent in grain hopper cars, was more severe due to a shortage of river barges for moving soybeans and grains in the inland waterways. During the 1976-78 period, periodic intervals of heavy grain movements and barged soybean test shipments out of Illinois and Iowa were subjected to delays in shipping, increased storage costs, and disrupted shipping schedules.

Rates charged for barging agricultural goods were unfettered by government regulation, and the carriers varied their rates in order to be competitive or to match seasonal changes in demand. To lessen the strain on

barge availability, the carriers charged premium rates during peak harvest periods and gave discounts during the off-season.

The barge rate in September 1977 was 7.8 cents per bushel, or two times the published tariff rate. During the October-December period, this rate increased to 3.5, or four times the tariff rate.

Soybeans tended to flow to market by the lowest cost mode or combination of modes of transport. Other factors were availability of transportation and market prices at destination. The lowest cost mode for moving soybeans from a terminal elevator on the Mississippi River to New Orleans was by unit-grain train or by barge.

The unit-grain trains, with 50 to 100 hopper cars, operated round trip continuously from the terminal elevator to the export elevator. Transport charges were 30 percent less, loading and unloading time was reduced in half, and very little time was lost by demurrage (idle car days). The railcar utilization rate was four times greater in a grain-train movement than it was when hopper cars were moved singly or in small lots.

Most of the soybeans which moved to the Gulf Coast elevators were barged down the Mississippi River from terminal elevators in Illinois, Iowa, Missouri, and Indiana. The barges were mainly of the 195-foot type with a 1,500-ton cargo hold. The cost of moving soybeans by barge averaged about 1 cent per ton-mile. Rail costs were about four times higher, and truck rates were 10 times higher.

Figure 7.—Trimming machines used to load soybeans on a tween-decker at a U.S. East Coast port.

All the test shipments were carried overseas in freighters or bulk carriers. Three of these shipments were carried on freighters which were relatively small ships of 10,000- to 15,000-ton capacity. These ships had to be loaded in the tween-decks in order to carry a full load of grain, which required trimming machines (fig. 7) that shot the beans at great velocity against the sides of the ship. Splits in these shipments increased 14, 22, and 18 percent, and FM increased 68, 36, and 26 percent between origin and destination, probably due to the use of these trimming machines.

All the other test shipments were carried on bulk carriers of 30,000- to 40,000-meteric-ton capacity, which predominate in the grain-carrying trade. All the bulk carriers were highly automated, with five to seven holds, and were loaded and unloaded with ease except during cleanup. (See figure 8.)

Insect Infestation

Insect infestation is a problem in the movement of grain and soybeans to overseas markets, and it was evident in the test shipments unloaded in Japan. Customs inspection at arrival in Japan was thorough, and the detection of a single insect by customs officials necessitated fumigation of the entire ship. Of the 12 soybean test shipments which arrived in Japan, seven required fumigation because of insect infestation. The insects detected varied, and included the almond moth, rusty grain beetle, and grain weevil. These seven test shipments were delayed 48 hours during the fumigation process, and the receivers were charged with additional fees for the fumigation.

Researchers were told by the management personnel of six grain elevators in Japan, Japanese customs officials, and officials of Japanese weighing and inspection companies that most U.S. soybean shipments arriving in Japan require fumigation. A survey conducted for researchers showed that out of a total of 72 U.S. ships loaded with soybeans which arrived in Japan from January to July 1978, 62 required fumigation.

Weight Discrepancies

Differences between invoice weight and "landed weight" were a continuous problem in overseas soybean shipments.[20] Because of a continuing interest in

[20]Invoice weight was the weight of shipment at time of loading. "Landed weight" was the weight of shipment at the time of unloading at destination.

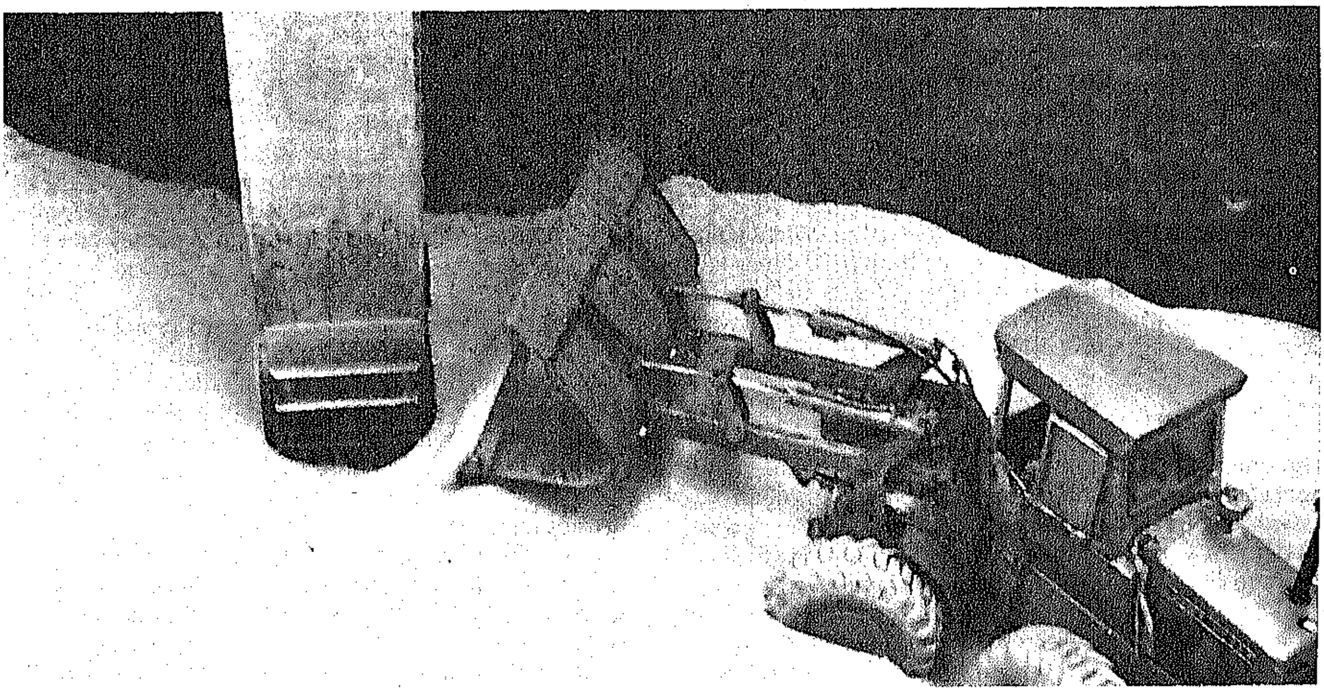


Figure 8.—Rubber-tire tractor vehicle used to clean up ship's hold.

the problem of weight shortages, the researchers studied the problem of soybean weight shortages in Japan. Of the 12 test shipments destined for Japan, there were weight shortages on six shipments varying from 0.4 to 0.8 percent; the remaining six shipment destination weights corresponded to the invoice weights. The average of the weight shortages on the six shipments amounted to 0.5 percent. Some of these shortages were caused by split deliveries and others by legitimate scale tolerances, the legal tolerance for error being one-tenth of 1 percent.

Quality

U.S. soybeans.—Analysis of the test shipments for oil, protein, and free-fatty acids (table 7) failed to provide any significant information on quality loss or deterioration from origin to destination. The weighted average of the oil varied only slightly from 21.2 percent at origin to 21.3 percent at destination. Protein also varied slightly from 40.2 at origin to 40.3 percent at destination. The same held true for the free-fatty acid count which changed only from 0.6 percent at origin to 0.7 percent at destination.

Analysis for neutral oil loss of origin and destination samples was made on two shipments. (See table 8.) In shipment No. 32E507, the free-fatty acid content was 0.6 percent in both origin and destination samples. Neutral oil loss in these samples was 3.34 percent and 4.15 percent for origin and destination, respectively, indicating a decrease in quality of oil in the soybeans. In shipment No. 36S120, the free-fatty acid content increased from 0.6 to 0.7 percent during shipment, while the neutral oil loss increased from 4.22 to 4.87 percent between origin and destination. The neutral oil loss on subsamples varied considerably, as was the case in all other analyses.

Brazilian soybeans.—The quality of four shipments of Brazilian soybeans is analyzed in table 9. The oil content (dry basis) was about 1 percent higher than that found in U.S. shipments, ranging from 20.0 to 22.1 percent. Protein content was about the same as that found in U.S. soybeans, ranging from 38.5 to 41.1 percent in Brazilian beans. Free-fatty acids ranged from 0.7 to 1.2 percent in the Brazilian soybeans, about the same as in beans from the United States. Neutral oil losses were also about the same in soybeans from both countries, ranging from 4.03 to 4.98 percent in those from Brazil, compared to a range of 4.15 to 4.87 percent in U.S. soybeans. Subsample variation was about the same for Brazilian and U.S. soybeans.

Table 7.—Quality analysis of U.S. soybeans sampled at U.S. origin and European and Far East destination, 1976-78

Shipment No.	Origin: Oil (dry basis)	Origin: Protein (dry basis)	Origin: Free-fatty acids	Origin: Splits	Destination: Oil (dry basis)	Destination: Protein (dry basis)	Destination: Free-fatty acids	Destination: Splits
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
11A414	21.0	40.0	0.6	10.1	20.8	40.6	0.6	9.8
12A522	21.1	39.9	.4	12.5	20.9	40.7	.6	13.2
14A619	21.3	40.0	.5	10.0	21.0	40.3	.5	6.8
15A620	21.4	40.6	.4	12.5	21.6	40.4	.7	14.4
16A627	21.3	40.1	.7	11.7	21.1	40.1	.5	9.0
17A703	21.0	40.1	.4	10.7	21.1	39.6	.5	11.5
18A825	21.7	40.2	.6	10.9	21.3	40.4	.7	12.8
19A315	20.7	39.9	.8	13.1	20.6	40.3	.8	14.0
20A413	20.4	40.6	.5	9.2	20.9	40.9	.6	10.4
22A717	21.3	40.0	.5	12.1	21.3	40.6	.9	12.2
25E207	21.4	41.1	.4	9.8	21.6	40.8	.5	10.7
28A180	22.3	39.1	.3	9.8	21.3	39.9	.4	8.2
29E277	21.6	39.6	.5	10.2	21.5	39.7	.6	10.5
30A218	20.2	41.0	.5	17.1	20.6	40.2	.6	20.8
31E227	21.7	40.8	.7	16.3	21.6	40.6	.6	19.0
32E507	21.0	40.4	.6	13.4	20.4	40.0	.6	15.9
33E727	20.6	40.0	.5	18.7	20.8	40.2	.7	22.1
34A416	20.9	40.5	.6	10.6	21.1	40.6	.5	12.4
36S120[1]	21.7	39.6	.6	5.8	21.6	41.0	.6	6.8
40A119	21.7	39.7	1.1	11.8	21.7	40.2	1.3	13.0
42A318	21.6	39.9	1.0	12.8	22.1	39.4	1.0	12.7
Weighted average	21.2	40.2	0.6	12.2	21.3	40.3	0.7	13.8

[1]Shipment loaded in Toledo, Ohio, traveled through St. Lawrence Seaway, and unloaded at Port Cartier, Canada.

Table 8.—Quality analysis (neutral oil loss) of selected U.S. soybean shipments to European destinations, 1977

Shipment No.	Origin: Free-fatty acids	Origin: Range of neutral oil	Origin: Neutral oil loss	Origin: Moisture content	Destination: Free-fatty acids	Destination: Range of neutral oil	Destination: Neutral oil loss	Destination: Moisture content
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
32E507	0.6	1.4-5.3	3.34	9.7	0.6	2.6-5.8	4.15	10.9
36S120	.6	3.3-7.0	4.22	12.5	.7	2.2-6.8	4.87	12.5

Table 9.—Quality analysis (neutral oil loss) of Brazilian soybeans sampled at European destinations, 1976-77

Shipment No.	Oil	Protein	Free-fatty acids	Range of neutral oil loss in subsamples	Neutral oil loss	Moisture content
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
24B924	22.1	41.1	0.9	2.9-6.3	4.03	10.2
26B102	20.0	38.9	.7	2.3-6.9	3.99	10.6
38B119	21.6	38.5	1.2	2.2-6.8	4.49	10.6
39B131	21.7	38.6	1.1	4.0-6.7	4.98	11.2

Conclusions and Recommendations

Soybeans were subjected to continuous movement, repeated handlings, frequent transfers, and numerous elevations between the farm and the final foreign customer. This resulted in breakage and deterioration that concerned overseas buyers. Each time soybeans were handled, the cost increased about 2 cents a bushel and breakage increased at a cumulative rate. Improvements or alternatives that can be developed to reduce the number of handlings will contribute significantly to reducing both costs and breakage.

The increase in FM indicates that beans are breaking up in movement between origin and destination. The single most important item in the content of FM was fines, or broken beans. Mechanical handling, loading and unloading at high speed, and gravity drops into storage silos and large bulk carriers caused the soybeans to break. This is partly confirmed in table 2 which shows a weighted average of FM of 1.6 percent at origin, with the actual range of samples from 0.2 to 3.3 percent, and a 1.8-percent weighted average at destination, with the actual range of samples from 0.2 to 9.9 percent.

The "real" FM, made up of dirt and sand particles, weed seeds, and other grains commingled during handling of the soybeans, was generally aggravated by the spout-line or the natural separation phenomenon, which resulted in concentrations of 15 to 20 percent or more of these components. This highly concentrated area of broken soybean particles and FM deteriorated more rapidly than the rest of the load due to increased dust and fungi.

In overseas sampling of test shipments researchers relied mainly on FGIS manual sampling procedures.[21] Manual sampling by probe or Ellis cup gave consistent results where grid patterns and sampling instructions were definitely prescribed and carefully executed, although Ellis cup samples were more dependable than those drawn by probe.

The pneumatic unloading systems used overseas, as well as repeated handling, increased the amount of splits. The increase in splits from 12.2 percent at origin to 14.2 percent at destination is also significant, even though it is still well within the grade 2 limit of 20 percent.

[21]Mechanical sampling systems are being temporarily installed in Italy and Belgium by USDA for sampling soybean test shipments.

The information developed on fines indicates that soybeans were breaking in handling and that a significant portion of FM was actually fines or broken soybeans. This shows that there was significant breakage in soybeans during handling which was translated into heavy monetary losses. For instance, the value of U.S. soybean exports in 1977 was $4.4 billion. Applying information in table 5, which shows a weighted average of 0.96 percent of the sample for fines, we arrive at a figure of $45 million, which represents losses due to fines. Large modern bulk carriers with deep holds, combined with heights of 100 feet free-fall, aggravated the problem of splits and FM and increased the fines.

Although prices of soybeans continued to fluctuate due to the daily supply and demand situation, grade factors such as FM and splits had little effect on prices. The end-use factors of oil and protein content had little effect on soybean prices either, although they concerned the buyer more than some of the grade factors currently used.

On the basis of the data collected and from observations made by researchers during the period of this study, it appears that damage from conveyor belt speeds was not significant. More damage was inflicted by certain handling methods and equipment used for transferring the soybeans, such as screw augers, trimming machines, and pneumatic systems.

The costs of moving soybeans from the farm or country elevator to the export elevator in the United States were greater than those for moving the soybeans from the United States to a foreign port. Therefore, it is in the area of domestic U.S. transportation that studies of alternative modes or methods are needed.

At times the shortage of hopper cars restricted the movement of soybeans from the country elevator to the terminal elevator. The hopper car was the more efficient type of railcar for moving soybeans and its use in a unit train providing a fast and inexpensive overland movement.

In certain areas such as the Illinois-Mississippi River route to New Orleans, the barge or truck-barge combination provided an inexpensive way to move soybeans. The shortage of barges during harvest presented a serious problem in the movement of soybeans to New Orleans.[22] Due to port congestion, delays in loading barges by marine legs reduced the availability of

[22]The poor condition of Locks and Dam 26 on the Mississippi River also caused considerable delays in barge movements to New Orleans.

barges. Some elevators installed high-speed mechanized systems with which barges could be unloaded in about one-fifth the time required by conventional systems.

The demands for larger unit volumes and greater productivity were evident in the area of transportation. With the hopper-car unit train replacing the boxcar, loading and unloading times were speeded up greatly with the filling and discharging of 100-car trains in under 24 hours. The size of grain bulk carriers has increased from 15,000- to 20,000-ton cargoes to 35,000-to 70,000-ton cargoes. Barges on the inland waterways, which had carried 32,000 to 35,000 bushels, are now carrying 55,000 to 60,000 bushels. Because of these improvements in transportation and the general efficiency of the U.S. grain marketing and distribution system, grain has become the least costly delivered raw material.

Although weight shortages remain a problem, there has been a definite improvement, probably due to the assumption of the weight function by FGIS as specified in the Federal Grain Inspection Act of 1976. The shortages indicated in six of the test shipments studied in 1977 were 0.5 percent of the total shipment in each case, an improvement over the 0.9 percent shortages found in 1976. On 3,551,000 metric tons of soybeans imported by Japan during 1977, there was a weight shortage of 12,408 meteric tons, or 0.35 percent. During the first 5 months of 1978, 1,708,000 metric tons of soybeans were imported by Japan with a shortage of only 4,437 metric tons, or an average shortage of 0.26 percent, a decided improvement.

Another serious quality problem in marketing soybeans is insect infestation. This is a continuing problem, and proposals such as the storing of soybeans under low temperatures have been considered.

Deterioration occurs within all stored grain or soybeans, whether or not it is infested with insects. Insects, high temperatures, high relative humidity, and high moisture alter the rate of deterioration. Losses due to insect infestation are serious because they generally do not impact on the initial or the intermediate soybean handlers, but add additional costs to the receivers or processors. Soybeans shipped out of the warm and humid Gulf ports provide ideal conditions for insect infestation and for subsequent growth in transit to overseas destinations. Part of the problem consists of differences between U.S. Standards for Grain, which permit a grain cargo to contain a few insects and not be graded "weevily," and Japanese customs regulations, which require fumigation of a whole ship if only a single moth or insect is detected during customs inspection.

In the next phase of this soybean study, additional research is planned in some of the areas cited above for the purpose of identifying improved handling techniques that will neither increase the cost nor deter the movement of soybeans into or out of grain elevators.

Oil and protein contents of undamaged soybeans shipped did not vary significantly from origin to destination. However, free-fatty acids content did increase during shipment and no loss in protein content was detected in destination analysis.

Neutral oil loss was ascertained on two shipments. One shipment with no increase in free-fatty acids showed an increase in neutral oil loss from 3.34 percent to 4.22 percent, an additional loss of 0.9 percent. Another shipment with only 0.1-percent increase in free-fatty acids had a neutral oil loss increase of 0.7 percent. These increases indicate deterioration in oil quality from the United States to overseas destination.

Translated into a dollar figure, this neutral oil loss represents a considerable monetary loss to both the farmer and shipper. For instance, the neutral oil loss in shipment No. 32E507 amounts to $14,000, and in shipment No. 36S120 it amounts to $11,000.[23]

All future studies of quality loss in shipment should include neutral oil loss since this factor is a meaningful measurement of the quality of the oil in the soybeans.

---

[23]When the neutral oil loss increases 1 percent, the value of a ton of soybeans (containing this oil) will be decreased by about $1.

Appendix

Example 1

The following sampling procedures shall be used at destination for sampling soybeans for the U.S. Department of Agriculture at the specific locations or circumstances:

Samples are to be taken from all of the soybeans in a specified hold or holds at all locations where the hold or holds are unloaded.

At least one sample should be made up for a barge regardless of the barge size if the barge is sampled by pelican and loaded from only one hold. If two holds are used, a separate sample shall be made for each hold.

Where diverter-type mechanical samplers or Ellis cup samplers are used, one sample should be made up for each 1000 metric tons that have been unloaded.

Pelican sampling should be performed if at all possible during the loading of barges. A pelican cut should be taken from the soybeans running from the spout every 10 minutes. If more than one spout is running into the same barge, a sample should be taken from each spout. If the soybeans from each spout are coming from different holds, the samples are to be kept separate.

Barges shall only be probed when pelican sampling cannot be performed. When probing is required, probings are to be made along each side and in the center of the barge after the barge has been filled all over to a depth that is no greater than the length of the probe being used. After sampling at this layer, the barge can be filled all over again to a depth no greater than the trier length. The probings should start on each layer about 5 feet from the bow of the barge and continue towards the stern with probings being made about every 7 feet. The side probings should be made about 4 feet from the side of the barge.

The probing of ship holds should only be done when a portion of the hold has been or will be unloaded at another port or elevator where pelican sampling of barges, a diverter-type mechanical sampler, or an Ellis cup is used. When probing is required it should be done according to examples 2 and 3. Probing is to be done before loading starts at the elevator where probing is required. Probing is to continue as soybeans are unloaded to the depth probed. Samples are to be combined so that there are three layers in the ship—top, middle, and bottom. This will result in five samples being made up for the top layer, five samples for the middle layer, and five samples for the bottom layer. The five samples in each layer will be from the bow port, bow starboard, center, after port, and after starboard areas of the hold.

At the Toyo Oil Mill in Chiba, the Ellis cup is to be used to sample soybeans at the end of the belt. Every 5 minutes, take a sample by passing the Ellis cup from the right side to the left side of the belt and emptying the cup, then passing the cup from the left side to the right side of the belt and emptying the cup.

At the Hohnen Oil Mill in Shimizu, the diverter-type mechanical samplers are to be used. Every 5 minutes, a cut of the flowing stream of soybeans is to be taken with each diverter. Samples taken by diverters A-1 and A-2 are to be combined and samples taken by diverters B-1 and B-2 are to be combined. To take a single cut with a diverter, open the door, clean out the diverter discharge on diverter A-1, and make a pass with the diverter. Throw this por-

tion away and immediately make another pass. Save this portion as the sample and put it in the sample container for diverters A-1 and A-2. Follow the same procedure for diverter A-2. Also, follow the same procedure for diverter samples from diverters B-1 and B-2. The samples on diverters A-1 and A-2 and B-1 and B-2 should also be kept separate and identified as to the hold the soybeans are being taken from on the ship.

At Konan Futo Co., Ltd., in Kobe, the Ellis cup should be used on the belt with the low rate of feed similar to the way samples are taken at Chiba. If the Ellis cup fills up before the cross section is completed, three samples are to be taken at a time by taking one sample from the center of the belt and one sample each near the sides of the belt taken in the area half way between the center of the belt and the edge of the soybean stream. If sampling cannot be done with the Ellis cup at Konan Futo, the sampling should be performed as described above at the end of the belt at Yoshihara Oil Mill where the soybeans come from Konan Futo.

At Nisshin, Yokohama, the diverter-type mechanical sampler should not be used until a satisfactory secondary divider is installed. When a satisfactory secondary divider is installed, samples should be taken by the diverter with a diverter cut being taken about every 6 metric tons. To build a satisfactory secondary divider, it should be constructed similar to a Boerner divider. A Boerner divider may be used as the secondary divider while a modified divider is being constructed.

When the quantity of grain has been unloaded, the sample that has been collected is to be poured through the Boerner divider and reduced to a quantity of at least 1900 grams, but not more than 2100 grams.

The approximately 2-kilogram sample shall then be placed in a polyethylene bag with a completed soybean transportation test sample data card.

Another approximately 2-kilogram portion of the remaining portion of the sample shall be placed on the sieve and the bottom pan so the sample can be shaken and the material in the bottom pan examined to see if insects injurious to stored grain are in the sample. If live insects are found, the number and Latin name of each should be recorded on the card with the sample being saved.

After unloading a hold at an elevator, a separate sample shall be prepared if the quantity the sample represents is more than 100 metric tons. If the quantity the sample represents is 100 metric tons or less, the sample shall be combined with the immediately previous 1000-metric-ton sample. The number of samples and the metric tons that it will represent can be determined by using the quantity in each hold and the quantity that will be unloaded at that elevator. This information is known by the stevedores. The quantity represented by the sample should be shown on the card.

With the card inside the polyethylene bag and the bag pulled down tight around the top to remove the air, the bag's top should then be twisted tightly so the metal clip can be applied about 1½ inches from the top of the bag.

The polyethylene bag should then be placed inside a canvas bag, and the top of the canvas bag tied with a string for closure.

Place in a fiberboard box no more than 8 samples in canvas bags and close the fiberboard box with nylon tape or strapping.

All fiberboard boxes containing samples for a ship should be sent as a group when unloading is completed to the Agricultural Attache at the American Embassy in Tokyo.

During unloading, the holds that are being unloaded should be observed for unusual conditions from the deck of the ship about every 2 hours. This will be beneficial in identifying quantities of low-quality soybeans that should be sampled separately. There will probably not be many cases when low-quality soybeans are observed.

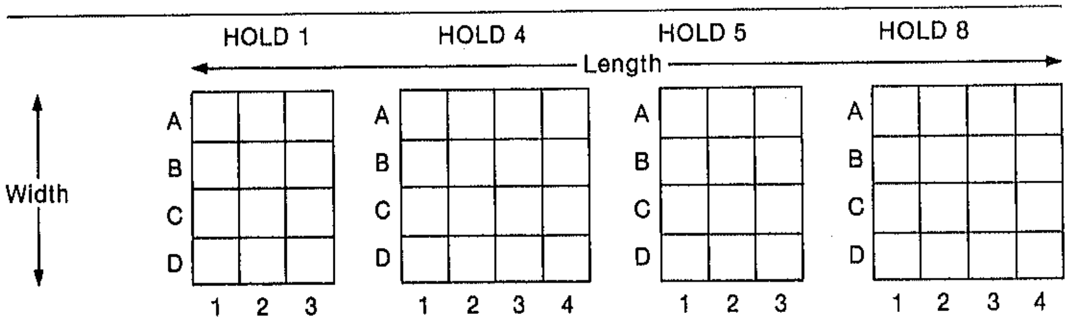
During sampling, the samples are to be protected in covered containers and stored in a secure place at night so that there is no chance that the samples are lost, changed, or stolen.

It will take special effort on the part of Japan Oilstuff Inspectors in some cases to arrange for changes in unloading procedures on ships or loading procedures on barges and handling procedures in elevators to obtain the samples with minimum complications.

Example 2

Grid Sampling Pattern for Shipment No. 13E613

I. Each ship hold is to be divided into cubic sectors, as indicated below.



II. Using a 6-foot probe obtain an adequate amount of grain from the sectors to be sampled to perform the needed sample analysis.

III. Samples should be labeled by:
Hold (1, 4, etc.), height of grain in center of sector being sampled, sector (A1, B3, etc.), date, and time.

IV. If at all possible have the grain within each hold unloaded as evenly as possible.

V. The list of sectors to be sampled from each hold is shown in Attachment 1. Arbitrarily, select one hold and obtain duplicate samples from each sector sampled. In addition, if possible, obtain samples from the fourth height listed under each hold at the bottom of the attachment.

VI. A recommended sampling procedure to use when measuring damage during unloading is shown in Attachment 2.

Attachment 1

Sectors To Be Sampled

Obtain samples from the indicated sectors in each hold at the height listed.

HOLD 1		HOLD 4		HOLD 5		HOLD 8	
Height	Sector	Height	Sector	Height	Sector	Height	Sector
42′	A1	47′	B1	53′	A3	41′	A3
	A2		B2		B1		B2
	B2		C2		B3		C1
	B3		C3		C2		C2
	D3		C4		C3		D1
30′	A2	36′	A2	46′	A1	24′	A1
	C1		A3		A2		A2
	C3		B1		B1		B3
	D1		B2		D2		D2
	D2		D1		D3		D4
6′	B3	18′	B3	6′	A1	12′	A1
	C1		B4		A3		B2
	C2		C2		C1		B3
	D2		D1		C3		C3
	D3		D4		D2		D4

If time permits, also obtain samples from these sectors:

12′	A1	53′	B3	18′	A1	35′	A1
	B2		C1		B2		A2
	B3		C2		C1		A3
	C1		C4		C2		C1
	C3		D3		D2		D3

Attachment 2

Measuring Damage During Unloading

To measure damage incurred during unloading, it will be necessary to use an Ellis cup. For Ellis cup samples to be worthwhile, the source of all grain being sampled must be from the four holds in question and all grain unloaded from these holds should be subject to Ellis cup samples.

In obtaining Ellis cup samples:

A. Get cup sample every 5 minutes during unloading.
B. Composite the cup samples collected during each half hour.*
C. Obtain a sample using appropriate divider from the composites.
D. Identify the composites by time and indicate holds from which grain was obtained.

*Sampling rates are based on full unloading capacity—if unloading at reduced rate, adjust 30-minute time period in B. accordingly.

Example 3

Grid Sampling Pattern for Shipment No. 31E227

The ship to be sampled has four holds (two large and two small) and six hatch covers. Sample only one large (No. 2 or 4) and one small (No. 1 or 3) holds. The tonnage loaded is as follows:

Hold 1 — 2266 long tons
Hold 2 — 5055 long tons
Hold 3 — 1884 long tons
Hold 4 — 5012 long tons
14217 long tons—tonnage loaded

A. Small Holds Nos. 1 or 3

	1	2	3	4
A				
B				

Heights	Small Holds	
41′	A4	
	B3	
	A2	
	B1	
	B4	
	A1	
36′	B4	A4
	A3	B2
	B3	A1
27′	A3	B2
	B4	A1
	A2	B1

Heights	Small Holds	
21′	B1	B2
	A4	A3
	A1	B4
12′	A1	B4
	A2	B2
	B3	B1
6′	A1	A4
	B1	B4
	A2	A3

36 probe samples — small holds

B. Large Holds Nos. 2 or 4

	1	2	3	4	5	6	7	8
A								
B								

Heights	Large Holds			Heights	Large Holds			
41′	A1	A5	A8	21′	B1	B5	B7	
	B2	B6	A6		A2	A6	A8	
	A3	A7	B7		B3	B4	B6	
	B4	B8	B5		A4	A3	B8	
36′	A2	B5	B8	12′	B2	A4	A8	
	A1	A6	B6		A1	A5	B8	
	B3	B7	A7		B1	B5	B7	
	A4	A8	A5		A3	B6	A6	
27′	B5	B1	A7	6′	A1	B6	B5	72 probe
	A5	A2	B8		B2	A4	B7	samples —
	B4	B3	B6		A3	A5	A8	large holds
	A3	A4	A8		B4	A6	A7	

1. Each hold is to be divided into sectors. Label the sectors as shown above.
2. Using a 6-foot probe, obtain an adequate amount of soybeans from the sectors sampled.
3. Samples should be labeled by holds, heights of sector, sector (A1, B3, etc.), date, and time.
4. To measure damage incurred during unloading, it will be necessary to use the Ellis cup. Get Ellis cup samples only from the holds where probe samples were drawn. In obtaining Ellis cup samples:
   a. Get cup samples every 5 minutes
   b. Composite the cup samples collected during each half-hour. (If unloading at a reduced rate, adjust sampling accordingly.)
   c. Identify the composites by time and indicate holds from which soybeans were obtained.

*U.S. GOVERNMENT PRINTING OFFICE : 1980 O-310-945/QT-185